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SUITABILITY OF DEMOLISHED CONCRETE WASTE IN MODERN CONSTRUCTION & ITS 28TH DAY STRENGTH PREDICTION

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ABSTRACT

Normally coarse aggregate is the fractured stone obtained from rocks in hills or pebbles from river bed. Because of depletion of good conventional aggregate in certain regions, the need to find out substitute materials for coarse aggregate has become imperative for environment protection. Use of recycled demolished waste is one of the solutions because waste disposal problem is a growing problem. Also saving of energy requirement in construction industry with use of locally available aggregates is of prime importance, reducing environmental pollution. Demolished concrete waste is crushed to required size, depending upon the place of its application and crushed material is screened to appropriate sizes. An aggregate produced by demolished buildings is known as Recyclable Coarse Aggregates (RCA). Most of the research work in concrete technology is based with use of limestone as main Coarse aggregate. In this paper study is carried out to replace lime stone with locally available waste debris of dilapidated buildings for economical reasons and tried as replacement of lime stone with demolished concrete waste and green concrete is made, under the provision of 3 R's: Reduce, Recycle and Reuse. The amount of construction waste has been dramatically increased in the last decade, and consequently recycling of waste has become mandatory. Waste concrete is particularly crucial among the construction wastes. In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. In this research, concrete waste of demolished structure (Durg-Bhilai township old buildings) has been collected and crushed, cleaned washed before use to prepare fresh concrete. Many researchers state that recycled aggregates are only suitable for non-structural concrete application. However, findings of this research shows that the recycled aggregates from demolished concrete makes good quality concrete. Researchers have found that the slump of recycled aggregate concrete is more than the slump of concrete made of limestone coarse aggregate. Therefore use of demolished concrete waste as recyclable aggregate is tried in experimental study in this paper. Finally it is concluded that the demolished concrete of old structure serves as good quality coarse aggregate in making fresh concrete for new construction.

KEYWORDS: Recycle Construction Aggregate, Demolished Structure, Compressive Strength, Models, Waste Concrete

INTRODUCTION

The utilization of demolished concrete coarse aggregate for concrete work is investigated in this paper. Normal concrete is being produced from different types of concrete mixes and this imparts different property to the resulting concrete. The most important property of concrete is its compressive strength. For the purpose of this research work, recycled demolished waste concrete of dilapidated buildings, in Chatisgarh. The fine aggregate is normal sand obtained from river beds. For each type of coarse aggregate and types of cement used are OPC-43Grade, PSC, PPC.

Compressive strength to be monitored at 1 & 3 days for accelerated curing (boiling water curing) (BWC) and 1, 3, 7 and 28 days for normal curing (NC) at room temperature.

The Accelerated Curing Comprises

All cubes are cured with wet gunny bags for 23 hours and then placed in a tub of boiling water at 100 ^{0}C temperature for 3½ hours before they are tested. The other cubes are immersed in water bath at room temperature for 28 days. After 3 days, three cubes are taken out and placed in boiled water tub at 100^{0}C for 3½ hours before testing. The remaining cubes immersed in water at room temperature are tested after 7 and 28 days for their compressive strength. This mode of accelerated curing helps in achieving higher compressive strength even on 1st day after the casting.

Nominal Curing Comprises

Cover the concrete cubes with wet gunny bags for 1 days, and after that they are immersed in water tub upto 28 days, and testing of their compressive strength is done after 1,3,7 and 28 days. Test result show that concrete made from demolished buildings concrete aggregate has the highest workability. Highest compressive strength at all stages was noted with concrete made from demolished buildings aggregate. Compressive strength models are proposed as a function of curing period. Where concrete practitioners have options, aggregate of demolished concrete waste building materials is advisable to be used for concrete work as replacement of limestone.

SUBSTITUTE OF LIMESTONE IN CONCRETE

Most of the research work in concrete technology is based on use of limestone as Coarse aggregate. Aggregate occupies between 70% and 80% of the total concrete volume, and because of that the strength of aggregate is very important in the final strength of the concrete. Limestone may not be economically available at all places therefore alternative materials must be explored. The coarse aggregate plays following role in concrete:

- It increases the crushing strength of concrete.
- It reduces the cost of concrete, since it occupies major volume.
- It makes solid and hard mass of concrete with cement and sand.

Generally crushed stone locally available is only used as coarse aggregate.

Demolished Buildings R.C.C. Waste Converted as Coarse Aggregate

One of the significant problems nowadays is the accumulation and management of construction and demolition waste, which increases along with continuous spreading of urbanization and industrialization. Construction and demolition waste can be recycled and used as a raw material for new applications. Bhilai Steel Plant was commissioned in 1958. Large numbers of residential quarters were constructed at that time for working staff and labour. These building have now became dilapidated and are demolished to avoid life risks Photo-(1). Bulk of R.C.C. waste from slab, beams and columns are available. Specimen samples of demolished concrete waste, is collected to recycle the waste as coarse aggregate in making fresh concrete.

Photo 1: Buildings Being Demolished of BSP Quarters in Sector 6, Bhilai & Demolished Concrete Coarse Aggregate

Materials and Method

Commercially available O.P.C-43Grade, P.S.C and P.P.C. Cement types were used for this purpose. The cement has a specific gravity of 3.15. Coarse aggregates stated above found near to Durg-Bhilai township for construction in Chhattisgarh were used for the study. The fine aggregate is normal sand obtained from the river bed. Preliminary laboratory investigation was conducted to ascertain the suitability of using the aggregates for construction work.

EXPERIMENTAL SETUP & OBSERVATION SCHEDULE

The test cubes of different mix design, for determining the compressive strength in concrete lab have been casted as per schedule given below

- **First Batch of 18 Cubes for Each of the Grades:** M20, M25, M30, have been casted in 1^{st} week of Dec. 2013. The cement used was OPC-43 grade, PSC and PPC. 18 cubes for each type of cement were prepared with coarse aggregate as concrete demolished waste 20 mm size. All 6 cubes have been subject to accelerated curing remaining 12 were cured normally in water at room temperature.
- 3 cubes of each mix were tested for compressive strength after 1, 3, 7 and 28 days in turn and average result of 3 cubes test is accepted as true compressive strength.

Figure 1: Concrete Test Cubes Casting and Accelerated Curing in Lab

Specimen Making, Casting, Curing and Testing of Specimen

There are three sets of mix ingredients as shown in Table 1. The required volumes of mix ingredient were measured and mixing was done thoroughly to ensure that homogenous mix is obtained. Demolished concrete waste as coarse aggregate 18 cubes of sizes (150x150x150 mm) were casted according to standard specifications and 3 specimens

were tested after 1 day, 3 days, 7 days, 28 days after normal curing in water and after 1 day and 3 day normal curing and accelerated curing system specified above i.e. after 23 hours of casting, the concrete cubes with demolished concrete were kept in boiling water tub at 100^0C for 3.30hrs±5min before testing.

Calculations

The Compressive strength can be calculated by dividing the max load applied to the area of the cube. The formula for finding the Compressive strength is,

C = P/A, Where, P = Max load applied on the specimen, A = Area of cross section of the specimen

Eg: P= 50800kg, A = (150X150)mm, Thus, C = (50800kg X 9.81)/(150 X 150) = 22.59MPa

Similarly compressive strength of other cubes can be calculated.

Analysis of Results

Table 1: Observed Values of Compressive Strength

No.	Mix Grade	Mix Proportion Cement : Sand : C.A	W/C Ratio
1	M20	1:1.756:3.061	0.575
2	M25	1:1.540:2.690	0.52
3	M30	1:1.460:2.550	0.50

1st Batch May 2013 – Normal Curing for 1,3,7,28 Days Immersed in Water at Room Temperature –Cement OPC-43 Grade Av. Compressive Strength Test after No. of Days Curing

No.	Mix Grade	1 Day NC (N/mm^2)	3 Day NC (N/mm^2)	7 Day NC (N/mm^2)	28 Day NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	3.36	8.59	16.74	22.15	20	28.25
2	M25	4.01	11.01	19.65	26.22	25	33.25
3	M30	4.80	12.99	22.00	30.22	30	38.25

1st Batch May 2013 – Normal Curing for 1,3,7,28 Days Immersed in Water at Room Temperature –Cement Ppcav. Compressive Strength Test after No. of Days Curing

No.	Mix Grade	1 Day NC (N/mm^2)	3 Day NC (N/mm^2)	7 Day NC (N/mm^2)	28 Day NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	3,44	9.58	16.22	22.66	20	28.25
2	M25	4.06	10.85	18.59	25.55	25	33.25
3	M30	4.74	14.68	22.66	30.59	30	38.25

1st Batch May 2013 – Normal Curing for 1,3,7,28 Days Immersed in Water at Room Temperature –Cement PSC Av. Strength Test after No. of Days Curing

No.	Mix Grade	1 Day NC (N/mm^2)	3 Day NC (N/mm^2)	7 Day NC (N/mm^2)	28 Day NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	3.48	9.81	17.55	23.10	20	28.25
2	M25	3.90	10.71	18.66	25.03	25	33.25
3	M30	4.38	11.81	20.22	27.55	30	38.25

Table 2: Observed Values of Compressive Strength - Coarse Aggregate – Demolished Concrete Waste 3rd Week May 2013– Accelerated Curing for 3½ Hrs. in Boiling Water –Cement OPC 43 Grade Av. Strength Test after No. of Days Curing

No.	Mix Grade	23 Hrs NC & 3 ½ Hour BWC (N/mm^2)	3 Days NC & 3 ½ Hour BWC (N/mm^2)	7 Day NC (N/mm^2)	28 Day NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	18.19	16.95	16.74	22.15	20	28.25
2	M25	21.33	20.00	19.65	26.22	25	33.25
3	M30	24.66	22.66	22.00	30.22	30	38.25

3rd Week May 2013– Accelerated Curing for 3½ Hrs. in Boiling Water – Cement PPC Av. Strength Test after No. of Days Curing

No.	Mix Grade	23 Hrs NC & 3 ½ Hour BWC. (N/mm^2)	3 Days NC & 3 ½ Hour BWC. (N/mm^2)	7 Day NC (N/mm^2)	28 Day NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	12.07	10.07	16.22	22.66	20	28.25
2	M25	14.81	11.78	18.59	25.55	25	33.25
3	M30	16.88	14.44	22.66	30.59	30	38.25

3rd Week May 2013– Accelerated Curing for 3½ Hrs. in Boiling Water– Cement PSC Av. Strength Test after No. of Days Curing

No.	Mix Grade	23 Hrs NC & 3 ½ Hrs BWC (N/mm^2)	3 Days NC & 3 ½ Hrs BWC (N/mm^2)	7 Days NC (N/mm^2)	28 Days NC (N/mm^2)	Standard Value (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	11.33	11.11	17.55	23.10	20	28.25
2	M25	12.70	11.33	18.66	25.03	25	33.25
3	M30	13.77	12.66	20.22	27.55	30	38.25

Normal Curing VS Accelerated Curing for M20 mix, DMC – coarse aggregate

Table 3: Compressive Strength Comparison of Mix M20

Mix Grade	1 Day	3 Days	7 Days	28 Days
Mn20-OPC	3.36	8.59	16.74	22.15
Ma20-OPC	18.19	16.95	16.74	22.15
Ma20-PPC	12.07	10.07	16.22	22.66
Ma20-PSC	11.33	11.11	17.55	23.10

N- Normal Curing A- Accelerated Curing

Compressive strengths curve for mix M20 are shown in Table (3). Compressive strength gain in case of accelerated curing is initially very high in all types of cement and abruptly falls before achieving the uniform gain. Normal curing marked in red line is uniformly increasing. The advantage of accelerated curing is that the test can be conducted after few hours which will help in assessing the quality of work done.

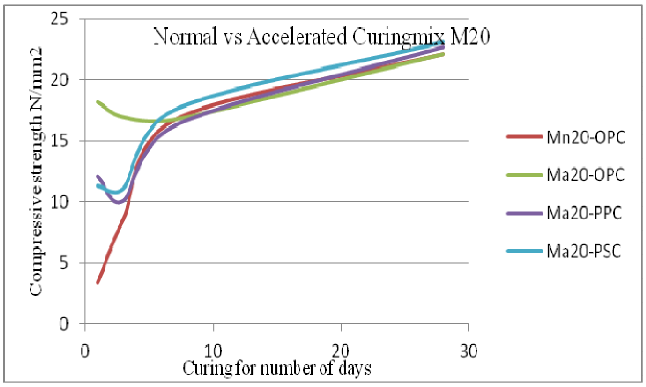

Figure 2: Normal Curing vs Accelerated Curing M20 Mix

Normal Curing VS Accelerated Curing for M25 mix, DMC – coarse aggregate

Table 4: Compressive Strength Comparison of Mix M25

Mix Grade	1 Day	3 Days	7 Days	28 Days
Mn25-OPC	4.01	11.01	19.65	26.22
Ma25-OPC	21.33	20.00	19.65	26.22
Ma25-PPC	14.81	11.78	18.59	25.55
Ma25-PSC	12.70	11.33	18.66	25.03
N- Normal Curing		**A- Accelerated Curing**		

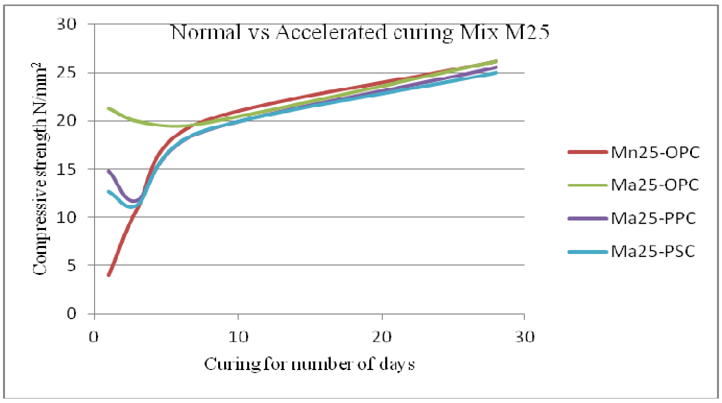

Figure 3: Normal Curing vs Accelerated Curing M25 Mix

The trend of results is similar to Normal Curing VS Accelerated Curing for M30 mix, DMC – coarse aggregate

Table 5: Normal Curing vs Accelerated Curing M30 Mix

Mix Grade	1 Day	3 Days	7 Days	28 Days
Mn30-OPC	4.80	12.99	22.00	30.22
Ma30-OPC	24.66	22.66	22.00	30.22
Ma30-PPC	16.88	14.44	22.66	30.59
Ma30-PSC	13.77	12.66	20.22	27.55
N- Normal Curing		**A- Accelerated Curing**		

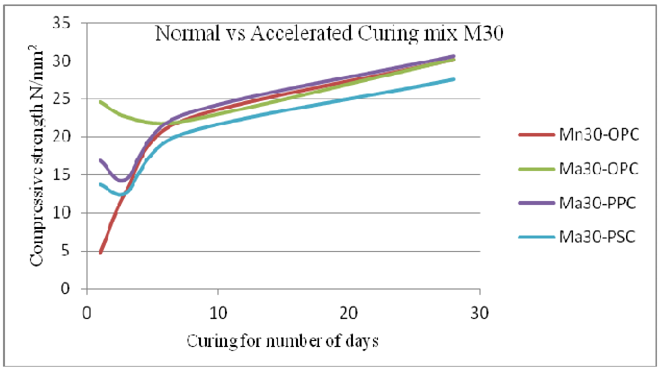

Figure 4: Normal Curing vs Accelerated Curing M30 Mix

The trend of results is similar to (4.3)

Comparison with IS M-40 Concrete Mix (Normal Curing)

In order to compare results of normal curing cubes M20, M25, M30 etc. with IS M40 grade concrete standard values[11], the observed data is represented in Table No. 6. Compressive strengths obtained after 3, 7, 28 days are then plotted in Figure 5. It may be noted that the standard strength of concrete IS M40 can be achieved within 28 days of curing. The IS code M40 curve is shown in purple colour line. It is noticed from Figure 5 that gain in strength for 1st day in case of IS M40 is little higher to 1st day normal curing of other grades of cement and after wards it has gain similar to normal curing method. There is dynamic similarity about the gain of compressive strength among different grades of concrete and IS M40 mix, therefore a similitude model can be developed for making practical applications.

Table 6: Strength Test after No. of Days Normal Curing at Room Temperature

No.	Mix Grade	3 Days	7 Days	28 Days	Standard Value in (N/mm^2)	Targeted Strength (N/mm^2)
1	M20	8.59	16.74	22.15	20	28.25
2	M25	11.01	19.65	26.22	25	33.25
3	M30	12.99	22	30.22	30	38.25
4	M40 (IS -code)	17.50	28.25	40	40	48.50

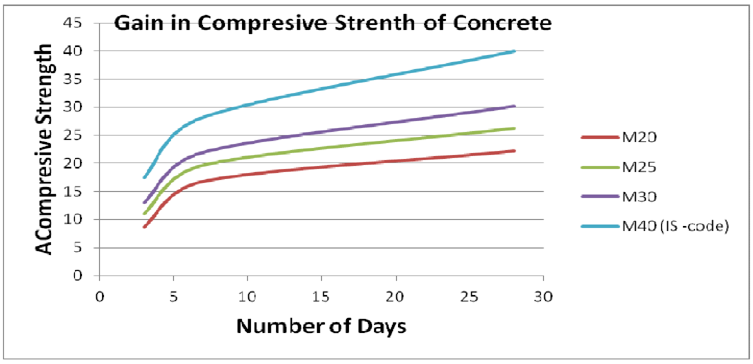

Figure 5: Dynamic Gain in Compressive Strength of Different Concrete Mix

Predictive Model of Compressive Strength for Mix IS M40 Grade

The compressive strength of concrete mix IS 40 with coarse aggregate as lime stone (20 mm size) is given in Table No. (6). Using these results, ideal curve equation can be determined to compute the compressive strength on

particular day for concrete *in-situ* as explained below:

Let the compressive strength gain be given by the equation: $\boxed{y = a(b)^x}$ [17]

Where y – Compressive Strength after particular number of days of curing

a - Factor comprising parameters of different mix design of concrete say M40,

b - Coefficient of number of days the system is subject to curing, type of curing and different water cement ratio used in the mix.

x - Number of days the cubes are subject to curing

The parameters ‘a’ and ‘b’ can be determined by substituting the standard values in the equation (1).

Table 7

Compressive Strength Curve						
Let the strength variation equation be:				$y=ab^x$		
Concrete						
Grade	Days	3	7	28		
M40	Comp. N/mm^2	17	28	40		
Solution for a and b Constants of the Required Equation						
No.	**x**	**y**	**Y**	**x^2**	**xY**	
			$\log_{10}y$			
	3	17	1.23045	9	3.69135	
	7	28	1.44716	49	10.1301	
	28	40	1.60206	784	44.8577	
	38	85	4.27967	842	58.68	
	Eqn.		3A+38B =	4.2797	--------- (1)	
			38A+842B =	58.679	--------- (2)	
On solving (1) & (2)		A=	1.26957	Therefore a =		18.602
		B=	0.01239		and b =	1.0289
	and final equation is $y= 18.602(1.029)^x$ ------(3)					
	Targeted strength $48.50 = 18.602(1.029)^x$					
Check for 1. strength after 14 days				=27.757		
Check for 2. strength after 28 days				=41.418		
Check for 3. targeted 48.50 N/mm^2 will be achieved after 33.50 days						

Predictive Model of Compressive Strength for Accelerated Curing

The compressive strength of concrete mix M30 with coarse aggregate as lime stone (20 mm size) is given in Table No. (2). Using these results, ideal curve equation can be determined to compute the compressive strength on particular day for concrete *in-situ* as explained below:

Let the compressive strength gain be given by the equation: $\boxed{y = a(b)^x}$ (1)

Where y – Compressive Strength after particular number of days of curing

a - Factor comprising parameters of different mix design of concrete

b - Coefficient of number of days the system is subject to curing, type of curing and different water cement ratio used in the mix

x - Number of days the cubes are subject curing in lab

The parameters ‘a’ and ‘b’ can be determined by substituting the standard values in the equation (1).

Table 8

Compressive Strength Curve M30 Grade of Concrete, Cement – OPC 43 Grade						
Let the strength variation equation be:				$y=ab^x$		
Concrete						
Grade	Days	1	3	7	28	
M30	Comp.	24.66	22.66	22.00	30.22	
Solution for a and b Constants of the Required Equation						
No.	**x**	**y**	**Y**	**x^2**	**xY**	
			$\log_{10}y$			
	1	24.66	1.39199	1	1.3919931	
	3	22.66	1.35526	9	4.0657797	
	7	22.00	1.34242	49	9.3969588	
	28	30.22	1.48029	784	41.448245	
	39	104.13	5.65298	843	56.303	
	Eqn.		4A+39B =	5.56997		
			39A+843B =	56.303		
On solving		A = 1.35044		Therefore a =		22.41
		B = 0.00431			and b =	1.01
	and final equation is $y= 22.41(1.01)^x$					
Check for 1. strength after 1 day				22.63		
Check for 2. strength after 28 days				29.62		

28th day compressive strength 29.62 N/mm^2 ≈ 30.00 N/mm^2

Equation $y= 22.41(1.01)^x$ for accelerated curing system shows that

Accelerated curing gives initial higher values of compressive strength over normal curing method. The strength even on 1st day is about 75-80% of value obtainable after 28 days. Therefore it is useful in taking decision about the quality of concrete work well in advance.

Table 9

OPC 43 Grade Cement					
M20 1 Day Accelerated curing BWC	**18.19 N/mm^2**	M25 1 Day Accelerated curing BWC	**21.33 N/mm^2**	M30 1 Day Accelerated curing BWC	**24.66 N/mm^2**
M20 28 Days Normal curing NC	**22.15 N/mm^2**	M25 28 Days Normal curing NC	**26.22 N/mm^2**	M30 28 Days Normal curing NC	**30.22 N/mm^2**

Concrete of OPC Cement With Different Mix Proportions and Different Water Cement Ratios, Gains Approx 80% of its 28 Days Strength by Normal Curing on 1st Day by Accelerated Curing

PSC Cement					
M20 1 Day Accelerated curing BWC	**11.33 N/mm^2**	M25 1 Day Accelerated curing BWC	**12.70 N/mm^2**	M30 1 Day Accelerated curing BWC	**13.77 N/mm^2**
M20 28 Days Normal curing NC	**23.10 N/mm^2**	M25 28 Days Normal curing NC	**25.03 N/mm^2**	M30 28 Days Normal curing NC	**27.55 N/mm^2**

Concrete of PSC Cement With Different Mix Proportions and Different Water Cement Ratios, Gains Approx 55% of its 28 Days Strength by Normal Curing on 1st Day by Accelerated Curing

PPC Cement					
M20 1 Day Accelerated curing BWC	**12.07 N/mm^2**	M25 1 Day Accelerated curing BWC	**14.81 N/mm^2**	M30 1 Day Accelerated curing BWC	**16.88 N/mm^2**
M20 28 Days Normal curing NC	**22.66 N/mm^2**	M25 28 Days Normal curing NC	**25.55 N/mm^2**	M30 28 Days Normal curing NC	**30.59 N/mm^2**

Concrete of PPC Cement with different mix proportions and different water cement ratios, gains approx 50% of its 28 days strength by normal curing on 1st day by accelerated curing.

CONCLUSIONS

From the experimental work carried out on “Recycle of Concrete Aggregates”, the following conclusion can be drawn:

- Due to accelerated curing technique adopted in this research work strength of concrete is high during initial stages, which is helpful in determining the early strength gain in concrete, which ultimately is helpful in predicting 28th day compressive strength of concrete.
- Accelerated curing technique adopted is very simple even the non-technical personals on the site can perform the experiment without difficulty. Also time required of getting results are short and instruments required are cheap and easily available, no skilled labour is required, temperature of water is to be maintained for required duration.
- Water absorption of RCA is higher than natural aggregate, hence 15% extra water has been added.
- The usage of RCA in concrete mixture is found to have strength in close proximity to that of natural aggregate and can be used effectively as a full value component of new green concrete.
- From foregoing study the similitude model for coarse aggregate for M30 grade concrete are:
- $y= 22.41(1.01)^x$ for recycled concrete from demolished buildings
- Where y – compressive strength to be determined for mix of concrete *in-situ*,
- x – Number of days the curing is done
- Above equations can give the value of compressive strength for M30 grade concrete at any point of time for respective coarse aggregate.
- The similitude model of M30 is a useful asset in construction industry to accept the quality of concrete *in-situ*.
- Finally it is concluded that recycling of demolished waste can offer not only the solution of growing waste disposal problem, but will also help to conserve natural resources for meeting increasing demand of aggregates for long time to come for construction industry and give sustainable environment protection.

The outcome of tests carried out in this research describes about the use of Recycled Aggregate in Construction. A process to get aggregate from demolition waste is developed and its basic properties are determined. Such recycled aggregate is tried to produce concrete of grades M20, M25 & M30 or similar other uses.

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